AD-A047 002   DAVID W TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CE--ETC F/G 9/5
TECHNICAL FEATURES OF ELECTRONIC CONTROLLERS USED FOR NUMERICAL--ETC(U)
AUG 76   B M SMITH, D J BURNETT, S S HART

UNCLASSIFIED   CMD-76-23   NL

| OF |
ADA047002

END
DATE
FILMED
| -78
DDC

ADA047002

12

TECHNICAL FEATURES

OF ELECTRONIC CONTROLLERS USED FOR

NUMERICAL CONTROL OF MACHINE TOOLS

Bradford M. Smith   David Taylor Naval Ship R&D Center

Denis J. Burnett   Naval Ordnance Station, Louisville, Ky.

Stanley S. Hart   Frankford Arsenal, Philadelphia, Pa.

Michael P. Kemler U.S.   Naval Shipyard, Philadelphia, Pa.

David Ruppe   Army Electronics Command, Fort Monmouth, NJ

COMPUTATION AND MATHEMATICS DEPARTMENT
DEPARTMENTAL REPORT

August 1976   Report CMD-76-23

DDC

RECEIVED

NOV 30 1977

A

DAVID
W.
TAYLOR
NAVAL
SHIP
RESEARCH
AND
DEVELOPMENT
CENTER

BETHESDA
MARYLAND
20084
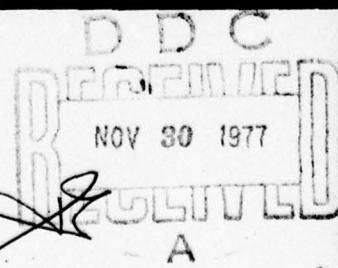
REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER CMD-76-23	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER *for period ending*
4. TITLE (and Subtitle) Technical Features of Electronic Controllers used for Numerical Control of Machine Tools		5. TYPE OF REPORT & PERIOD COVERED Final Report FY76
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Bradford M. Smith Michael P. Kemler Denis J. Burnett David Ruppe Stanley S. Hart		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS DOD Manufacturing Technology Advisory Group Subcommittee on Computer Aided Manufacturing		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Computation & Mathematics Dept. David Taylor Naval Ship R&D Center Bethesda, Md. 20084		12. REPORT DATE 19 August 1976
		13. NUMBER OF PAGES 31
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release

Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Numerical Control
Machine Tools
Computer Aided Manufacturing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report compiles the technical descriptions and user benefits of 123 different features commonly available on electronic controllers used for the numerical control of machine tools.

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73
S/N 0102-014-6601

FOREWORD

In any newly emerging technology, communication is often hampered by quickly changing definitions of terms. So it is with the field of numerically controlled (N/C) machine tools. The great advances being made in the electronics industry are enabling the manufacturers of N/C machine control systems to offer to their customers a wide variety of technical features. Some of these features are, of course, essential to the basic operation of the N/C machine, but many other features are offered as optional items to suit the varied needs of a wide range of customers.

In a recent study the DoD Manufacturing Technology Advisory Group Subcommittee on Computer Aided Manufacturing compiled the technical descriptions and user benefits of 123 different features commonly available on N/C controllers now being sold. The listing is published to promote a better understanding of N/C technology as well as to assist users in specifying N/C system requirements to better fulfill their individual needs.

NC CONTROL SYSTEM FEATURES

AUGUST 19, 1976

DATA INPUT FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
ASCII OR EIA INPUT CODING	Selects which of two coding systems is used for paper tape input information.	Gives a user versatility in an orderly changeover from the older EIA coding system to the new ASCII coding of data characters.
AUTOMATIC TAPE ERROR RE - READ	When errors are detected on paper tape input, the NC controller will automatically backspace and try to re-read the data before halting in error.	Ordinarily a tape error when detected causes a halt in NC operations. This feature attempts to recover automatically before initiating a program stop and possibly damaging the workpiece.
COMPUTER INTERFACE	A direct connection of the NC system with a remote computer for two way communication usually by a wire link.	Allows data exchange between NC system and a remote computer for purposes of status monitoring, NC programming, maintenance assistance or production control.
CONTROLLER EMULATION	NC controller can be configured to simulate a different controller in every respect as far as input data codes and functions are concerned.	Allows a user to re-run without modification old NC tapes originally created for another NC system. Enables rapid shifting of workload among similar NC machines.
DUAL PAPER TAPE READERS	Two paper tape readers are provided for versatility in production.	Often a shuttle loading machining center is set up for two different parts to be run alternately with one being set up as the other is being machined. Two tape readers are desirable.

1

DATA INPUT FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
KEYBOARD ALPHANUMERIC INPUT	Full alphanumeric keyboard allows operator to enter data, text, or special commands into the NC system.	Keyboard input enables operator to converse with the NC system or a remote computer. It allows him to enter data to modify machining sequence, to edit paper tape information, or to rerun the entire part program.
LEADING ZERO SUPPRESSION	Leading zeros used to fill up a data field in a block of tape data can be eliminated when using this feature. The data is assumed to be right justified.	Normally data fields within each block of tape data are of fixed length (i.e., 7 digits). Unused digits must be filled with zeros. This increases tape punching time and cost unnecessarily.
MAGNETIC TAPE INPUT	Data on machining sequence can be input by reel or cassette magnetic tape rather than the usual punched paper tape.	Magnetic tape is a more reliable, although more expensive, input data medium than paper tape. It is more compact – with one cassette capable of storing several reels of paper tape data.
MANUAL DATA INPUT	Ability for machine operator to enter digital data to the controller by way of a dial or push button input rather than by program tape.	Allows setup data to be entered or modifications to be made to machining data.
MULTI-BLOCK BUFFER STORAGE	Ability of paper tape reader to input several blocks of machine instructions and to store them for execution at a later time.	Minimizes wear on the tape reader resulting from constant start-stop. Allows controller to look ahead several instructions. Increases effective tape reading speed.

2

DATA INPUT FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
PAPER TAPE INPUT	The ability to read one inch wide perforated paper tape containing input data for the NC system.	Paper tape is the most popular method of reading data into an NC system. Most programming services are geared to producing paper tapes as output.
PARITY CHECK	Each data character read in is checked for proper parity to detect errors.	Detection of a parity error in a data character causes the controller to halt before the error can cause any damage to the machine or workpiece.
SINGLE BLOCK BUFFER STORAGE	The capability of temporarily storing instruction so that it is immediately available for action once the previous instruction has been executed by the controller.	Buffer storage lessens the need to wait for the paper tape reader to catch up to the machine's need for data. It enables the controller to look ahead at the next instruction while working on the present one.
TRAILING ZERO SUPPRESSION	Trailing zeros used to fill up a data field in a block of tape data can be eliminated when using this feature. The data is assumed to be left justified.	Normally data fields within each block of tape data are of fixed length (i.e. 7 digits). Unused digits must be filled with zeros. This increases tape punching time and cost unnecessarily.
USER DEFINED INPUT FORMAT	Allows the format of input data characters to be modified to suit different needs of a user.	Enables a user to easily configure his NC controller to accept data in a variety of formats. Useful in simplifying part programming, re using existing part program tapes, or interfacing the NC system with appropriate computer software.

3

DATA OUTPUT FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
CRT DISPLAY	An electronic Cathode Ray Tube with associated storage and character generation electronics is used for display of alphanumeric data pertaining to the NC machining operation.	Various data displays can be selected by the operator to assist him in efficiently monitoring, directing, and maintaining the NC system.
DATA TRANSMISSION INTERFACE	Electronic circuits which enable the NC controller to carry on two way communication of digital data with a remote computer usually by wire link or telephone circuit.	Allows data exchange between the NC controller and a remote computer for purposes of NC programming, status monitoring, maintenance assistance, program editing, or production control.
PUNCH TAPE OUTPUT	The ability to punch out one inch wide perforated paper tape by the NC system.	Used to provide a permanent record of the input data which was modified by manual editing during tape proveout, optimization by the operator, or part programmer.

4

DATA MANIPULATION FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
ABSOLUTE/INCREMENTAL INPUT	Input position data can be in either absolute coordinates or incremental movements from the last commanded position. Choice of coordinate data type can be designed in by the controller manufacture or can be made selectable either by a tape code or machine operator.	There are advantages to using both systems of position data. When both are provided, a programmer is free to choose the best one for his particular application.
ADD A NEW BLOCK OF DATA	Allows manual input of instructions that become a permanent addition to the input data that has been previously stored. Enables an operator to define a new block of machine instructions and merge it into the proper sequence of instructions.	Useful for initial prove out of tape data, for optimizing and editing existing programs, and for incorporating permanent changes to the stored tape data.
DELETE A BLOCK OF DATA	Allows a manual deletion of an instruction from the input data. The change remains in effect on subsequent runs.	Useful for modifying tape data during initial prove out, for optimizing machining sequences, and for incorporating permanent changes to the tape data.
DIRECT IPM AND RPM CODING	Allows coding of feedrates and spindle speeds on the input data to be in common units rather than special proprietary encoded formats.	Simplifies manual part programming and readability of paper tape data.
INCH/METRIC INPUT	Capability to select inch or metric programming on a single system without need to change feedback devices. May be selected by switch or by program control.	Allows processing of tape data coded for English or Metric system without need for changing electronics, gearing or feedback devices. Gives flexibility for the U.S. changeover to the Metric system.

5

DATA MANIPULATION FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
MODIFY A BLOCK OF DATA	Allows any information within a single block of stored tape data to be updated by manual operator input.	Useful for initial prove out of tape data, for optimizing and editing of existing programs, and for incorporating permanent changes to the stored tape data.
MOVE A BLOCK OF DATA	Allows manual input of commands which modify the sequence of execution of previously stored machine instructions.	Useful for initial prove out of tape data, for optimizing and editing of existing programs, and for incorporating permanent changes to the stored tape date.
PART PROGRAM STORAGE	Allows tape data for a machining sequence to be read in and stored in the controller prior to execution.	With tape data stored in controller memory execution is not limited by tape reader speed and is not hampered by tape reader errors. Additionally, the tape data can be previewed and edited prior to and during execution.

MAINTENANCE FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
AXIS CALIBRATION	The errors between actual position and commanded position are measured along each machine axis and are incorporated into an error table within the controller. Subsequent commands for positioning are modified by this error table to position the machine tool more accurately.	A user can re-run the calibration procedure as often as desired to compensate for machine wear. This technique relies upon the known principle that machine positioning errors are repeatable.
CONTROL DIAGNOSTIC CAPABILITIES	A sequence of tests can be performed by the controller as a self test of its major subordinate components. Discrepencies are displayed to the operator.	Self diagnositc tests have been designed into many pieces of electronics equipment to ease the task of maintenance.
FAULT DETECTIONS	Status lights indicate fault conditions such as following error limits, slide limit checks etc.	Rapid and automatic detection of system malfunctions.
LAMP TESTS	A single switch is provided which illuminates every indicator on the NC controller.	A quick visual scan can be made by the operator to detect any malfunction of panel lamps or digital displays.
MACHINE DIAGNOSTIC CAPABILITIES	A sequence of tests can be performed by the controller to exercise the various machine functions and compare actual results to expected values and display any discrepencies to the operator.	Diagnostic test performed on the machine tool can be used to pinpoint malfunctions or to indicate potential hardware problems. Results of these periodic tests will comprise a valuable long term history.
MANUAL TSST PANEL	Operator or maintenance technician can introduce a variety of test conditions to the controller and observe the results.	Simplifies the task of pinpointing problem areas and testing the overall condition of the NC controller.
REMOTE TESTING	Allows Transmission of data via telephone wires to diagnostic center.	Enables rapid and thorough testing of machine and controller.

NON MOTION CONTROL FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
AIR BLAST CHIP REMOVAL	Tape controller miscellaneous function controls high pressure air jets to clear chips away from workpiece.	Excessive chip buildup can cause damage to workpiece surface finish. Automatic air jets relieve operator of a tedius function.
AUTOMATIC TAPE REWIND	Rewinds input tape to the intial starting block after reaching the end of the program.	Saves operator time and prepares controller to start next part in the job lot.
BAR FEED	Advances bar stock material into the work area after previous part has been machined	Useful for machining multiple parts on a lathe.
CLAMPING	Miscellaneous codes on input tape are used for control of automatic workpiece holding devices.	Useful to speed setup and removal of parts from the machine table.
COOLANT SELECTION	Miscellaneous codes on input tape provide selection of type and amount of coolant.	Programmer can predetermine coolant use rather than relying upon machine operator.
CUT OFF CYCLE CONTROL	Severs machined part from raw stock at completion of machine cycle.	Useful for machining multiple parts on a lathe.
DWELL	Causes a halt of all machine functions for a discrete period of time.	Programmer often desires a dwell to give spindle time to stop. A dwell is often required to allow a previous machining command to finish; for example a change of spindle speed or transmission range.
FEEDRATE OVERRIDE LOCKOUT	Prevents programed feedrate from being modified by machine operator through feedrate override control.	Desirable for threading and tapping modes as well as insuring planned rate of production.

8

NON MOTION CONTROL FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
FEEDRATE SELECTION	Enables precise control of relative motion measured along the direction of cut from codes on the input tape.	A programmer need not rely upon machine operator to set proper feedrate.
REWIND TO REFERENCE CODE	Initiates a rewind of input tape to a specified reference mark previously coded onto the tape.	Helpful for program searching, to assist in setup of part, or to return to established reference or restart positions. Especially helpful where no sequence numbers are used.
SPINDLE ON/OFF	Basic control of spindle motor by tape input.	Allows programmer to intiate and terminate spindle rotation but relies upon machine operator to set speeds by gearing, belts, etc.
SPINDLE ORIENTATION CONTROL	Stops spindle and tool in a predetermined orientation.	With a single pointed boring tool in a known position, the programmer can back the tool off the part surface before a retraction.
SPINDLE RANGE SELECTION	Various ranges of the spindle drive train can be selected from miscellaneous input tape codes.	Enables programmer to control optimum selection of spindle speed range rather than having to rely upon machine operator.
SPINDLE SPEED SELECTION	Provides a complete control of spindle speed by input tape command.	Allows maximum versatility in controlling spindle speeds.

NON MOTION CONTROL FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
TOOL SELECTION (RANDOM)	Allows next tool to be loaded from any position in the automatic tool holder.	Saves tool loading time when several tools are to be reused at various points in the machining sequence.
TOOL SELECTION	The tool to be loaded into the spindle is taken from the next available location in the tool changer.	Gives basic tool loading capability but requires that tools must be arranged in the automatic changer in the order they will be used.
VARIABLE TOOL RETRACT PLANES	Sets a limit for the amount of tool retraction along the spindle axis when a retract sequence is required by a canned cycle or an input tape instruction.	A retract position register can be modified by tape commands to vary the retract plane position for different machining conditions.

MOTION CONTROL FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
ADAPTIVE CONTROL	A control system which uses automatic means to change the system parameters in a way intended to improve the performance of the system.	Feedrates and spindle speeds are modified to optimize metal removal rates or surface finish.
AUTOMATIC ACCELERATION/DECELERATION	A feature in the control system which enables the machine tool to accelerate and decelerate smoothly without the necessity for intermediate steps.	Tool path is modified to compensate for uneven tool wear, chatter, vibration, or cutter irregularities.
AUTOMATIC COLLISION ZONE PROTECTION	A boundary set by limit switches to prevent the collision of a tool with a vital portion of the machine tool.	Without this capability the programmer must calculate his acceleration/deceleration requirements and add intermediate blocks of tape data so that he does not exceed the machine servo drive capability.
BACKLASH COMPENSATION	Each axis always approaches the final position from the same direction.	Required to prevent unnecessary collisions due to a faulty program or a malfunction at the machine tool. This will decrease down-time due to maintenance repair of collisions.
CANNED PART SHAPES	A specific number of relatively simple part shapes can be "built into" the control. A simple method of command will cause the machine to cut one of the stored parts as many times as desired.	Improves machine accuracy of positioning systems.
CANNED MACHINE CYCLES	A set of operations that once initiated by the programmer are completely performed in a predetermined order by the controller.	Reduces amount of programming. For a large volume of a "family of parts", eliminates the need to repeatedly program common shapes. Ideal for positioning operations such as hole drilling, tapping, boring, reaming, etc. Canned Cycles decrease programming time and length of tape.

MOTION CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
CIRCULAR INTERPOLATION	The simultaneous and coordinated control of two axes of motion such that the resulting cutter path describes the arc of a circle.	Convenience feature, permits shorter tapes & tape preparation time, could permit faster cycle times with slower tape readers. Has minimum impact on part accuracy.
ERROR MAPPING	Storage and compensation for repetetative machine errors resulting from conditions such as non-orthorginality of axis motions.	Final commanded positions are much more accurate than non compensated machine would be.
FINE POSITIONING MODE	Controlled motion is used to reach a given within a high degree of accuracy end point with no path control during the transition from one end point to the next.	Controller insures that all axis motions approach the final commanded position from the same direction at a slow feedrate so that all backlash is removed from gearing.
FOUR QUADRANT PROGRAM-MING	A circular arc of any length (0° - 360°) can be programmed in a single block of tape date.	Without this added capability, circular interpolation blocks must be broken into segments at the points they cross over a coordinate system axis.
HELICAL INTERPOLATION	The simultaneous and coordinated control of one linear and one rotary axis with the rotary axis providing the controlling feedrate.	Useful for machining spirals and helices.
HIGHER ORDER INTERPOLATION	Generation of cutter paths following 3rd order or high polynomial segments.	Allows continuous path control along complex contours with relatively concise input data.
LEAD SCREW COMPENSATION	Automatic compensation for measured errors in each leadscrew.	Can be accomplished by cam compensation or by an error table in electronic memory. Reduces cost-improves accuracy.

12

MOTION CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
LINEAR INTERPOLATION	The simultaneous and coordinated control of two or more axis of motion such that all axes reach the commanded end point at the same time. Where all axes are linear motions, the resulting path is also linear.	Linear interpolation is essential for contouring operations.
MACRO PROGRAMMING	Storage of small common part programs in control unit and having them control machine motion at the direction of a second program.	Reduced part programming.
PARABOLIC INTERPOLATION	The simultaneous and coordinated control of two axes of motion such that the resulting cutter path describes a segment of a parabola.	Convenience feature, similar to circular interpolation. Primary use is in machining complex contoured surfaces.
PART ROTATION	Allows rotation of part program around 360° Primarily used in flame cutting or as an aid for machine setup.	Maximizes utilization of material.
PICTURE FRAME MILLING	This is an added capacity of a basic positioning control system to allow a controllable feedrate along my one axis.	A controllable feedrate allows the basic positioning system to do straight line milling. With this the programmer can clean up a surface for subsequent positioning operations like drilling and tapping.
POWER FAIL SAFE	In the event of a momentary or lengthy interruption of power to the NC controller this feature insures that there is no loss of stored data and that the machining sequence is brought to an orderly halt.	Power interruptions or low voltage conditions can often cause loss of stored data, malfunction, or even damage to the machine or workpiece. The Fail Safe feature seeks to minimize these problems. It is particularly valuable with stored program controllers.

MOTION CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
RETRACE	Permits operator to halt machine and back up along the path just cut.	Useful to recover from broken or dull tools in an orderly manner.
SFM FEEDRATE CONTROL	The control function used to maintain a constant relative velocity between the tool and the work in units of surface feet per minute.	Ideal for maintaining good surface finish on lathe facing operations.
STRAIGHT THREAD CUTTING	Machining an accurate thread on an NC lathe by synchronizing the spindle with the cutter feed to maintain a selected feed per revolution of the spindle.	A definite necessity for machining a thread with multiple passes of a single pointed tool.
TAPPERED THREAD CUTTING	Same as Straight Thread Cutting only on an angle.	Attainable by the same machine function as straight thread cutting.
TRAVEL LIMIT CHECKING	Warns operator of impending axis overtravel before the instruction is executed. Machine is brought to an orderly halt.	This feature detects errors in programming or setup that would otherwise cause the machine to move into the fail safe limit switches.
USER DEFINED MACHINE CYCLES	Allows a user to define his own special "canned cycle" machining sequence for subsequent use.	Often used machining sequence can be described in subroutine or macro like fashion as a "canned cycle" resident in the NC controller. The programmer can then call it out as he would any other canned cycle.

14

INFORMATION GATHERING FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
MANAGEMENT INFORMATION GATHERING	Controller has the ability to collect, format and transmit data regarding the instantaneous status of the NC system operation and the workload being processed	Status information can be used to update an on-line system capable of displaying to management overall survey data such as adherence to schedule, in-process inventory, and projecting maintenance problems. End of shift reports are easily generated.
PRODUCTION DATA LOGGING	Data is collected on part identification, quantities processed, setup time, run time, and jobs completed.	From this basic data on work flow and utilization, completion times on present jobs can be easily predicted and new jobs scheduled for startup.
SYSTEM UTILIZATION MONITORING	Data gathered from operator inputs and automatic sensors on the machine are totalized and formatted to present the current status of the machine operation.	Machine status data from the basic input for scheduling production, analyzing recurrent problems, and calculating plant operating capacity.

OPERATOR CONTROL FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
AUTOMATIC MODE EXIT/RETURN	Allows the operator to exit a cycle for varying reasons and return to the original position without any machine tool information loss.	Reduces time required for inspection of part, tool, etc. during machining cycle.
AXIS INVERSION	Permits the sign reversal for machine tool axis data. Not used in 2 axis motion.	Allows mirror image parts to be produced without requiring new tape.
BLOCK DELETE	Tape data blocks are ignored when preceded by a specific code. Operator has the ability to use or bypass any block containing a block delete code.	Used primarily to eliminate portions of a tape such as a last pass or spring cut on a threading operation. Also used with family parts programs to eliminate certain cuts or holes that may differentiate such parts.
BLOCK SEARCH	Locates a specific block on the tape. Accomplished by manually entering the block number at the control panel and initiating the block search operation.	Enables operator to rapidly locate any specific block of information in the tape.
CUTTER DIAMETER COMPENSATION	For cutter diameters different than programmed on tape, the operator can enter compensating values which the control will utilize in contouring.	Enables the use of cutters of different diameter than was originally planned. Reduces cutting tool inventory by permitting use of resharpened cutters without requiring new tape.
CYCLE START	Initiates the execution of the auto or single block mode of operation.	Initiates the tape reading function.
CYCLE STOP	Halts the control processing cycle. All axes motion and interpolation processing stop until the cycle start button is depressed.	Permits operator to stop tape cycle at any time.

OPERATOR CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
DISCRETE JOG	Movement of a selected axis for some predetermined distance and direction.	Used to reposition the machine setup and for precise movement of the tool for checking purposes.
DRY RUN	Allows cycling the part program through a non-cutting prove-out at a specified feed rate.	Permits program de-bugging at a'high feed rate therefore reducing prove-out time.
ELECTRONIC TOOL GAGING SYSTEM	Tool length and diameter are electronically read into the control by special tool gaging device. Machine control automatically compensates for the measured length of tool. Tool diameter information is used for tool change clearance calculations only.	Reduces tool setting time and errors. The method and necessity of entering tool set length on machine tape varies depending on control manufacturers.
EMERGENCY STOP	Initiates a cycle stop in the control and de-energizes specific outputs.	Used to stop the machine before some unforeseen collision can happen or when a machine malfunction occurs.
FEEDRATE OVERRIDE	Allows the operator to modify the programmed feedrate to a selectable percentage.	Eliminates tape changes where variances in material for a job would change the machinability beyond acceptable limits for a given feedrate.
GRID ZERO	Initializes each axis motion to the nearest grid point. The grid distance is the distance traveled for one cycle of the feedback transducer.	A basic convenience for setup as a separate operator control function.
FIXTURE COMPENSATION	Permits alignment of machine tool to fixture in lieu of changing fixture location to align with machine tool. Control automatically compensates for changing alignment values on machine tools with rotary axis motion.	Reduces setup time by allowing manual data input to align machine and fixture. Without fixture compensation the fixture must be physically moved to align with machine.

17

OPERATOR CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
FLOATING ZERO	Allows locating of the coordinate axis zero anywhere within the full travel of the machine tool.	Permits locating of part at any position on machine tool in lieu of a specified position from machine zero. Reduces setup time and tooling cost.
INTERPOLATION PLANE SELECTION	Allows for use of circular interpolation in the X-2 and Y-2 planes. Normal mode is X-Y plane.	Necessary for circular interpolation feature to function in any plane other than X-Y. Note: This is not a normal operator control function. It should be listed as a motion control function.
JOG	Manual movement of a selected axis in either direction at varying feedrates.	Used to move machine position where the exact distance or position is not required to be known.
OPTIONAL STOP	Provides the ability for the operator to have the machine stop whenever the proper code is read by the control. When switch is off the control will continue processing, ignoring the stop command.	Used extensively on first part run so that the operator can stop the machine to check his part. When the operator is satisfied with his setup, the stop can be ignored on following parts.
POSITION SET	Redefines present machine location to the manually inserted absolute values entered at the control panel.	This allows changing of setup at the control panel rather than having the change physical part location.
PROGRAM STOP	Causes the operating cycle to stop at the completion of the data block in which the proper code appears.	Allows programmer to interrupt tape processing at any predetermined block of the tape. Note: This is not an operator control function. Should be listed as a motion control function.

18

OPERATOR CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
RAPID TRAVERSE	Maximum positioning velocity.	Time saving function that positions the machine at a much greater velocity than would normally be used as a cutting feedrate.
REFERENCE ZERO	Causes all axis drives to move to a fixed, repeatable position for initialization of part program.	A basic convenience for setup of machining jobs.
REMOTE CONTROL CAPABILITY	Panel devices are physically separate from a skeleton control or the control is physically removed from the machine tool.	Allows some controls to be located closer to machine and normal operator position for setup.
SET ZERO	Initialized all axes to their present position.	A basic convenience for setup.
SLIDE HOLD	Allows a controlled decelerated stop of machine axis motion with no loss of axis position information. Motion remains stopped until commanded to resume.	Eliminates time lost in re-initializing machine tool when a temporary axis motion stoppage is required.
SPINDLE RETRACT	The movement of the cutter away from the work piece. This motion can be accomplished either in tape or jog mode.	Allows operator or programmer to move cutter away from work.
SPINDLE ROTATION SELECTION	Allows operator to manually select direction (CW/CCW) of spindle rotation.	Necessary for manual machining function.
SPINDLE SPEED OVERRIDE	Allows the operator a means of varying the programmed spindle speeds.	Eliminates need for new tape when all programmed information except spindle speed is correct.

OPERATOR CONTROL FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
TABLE INTERLOCK BYPASS	Provides additional spindle face positioning when tool configuration is such that additional machine travel will not result in a table/head collision.	Used to override the interlock zone built into the machine tool.
TAPE REWIND	Automatically returns the tape to the initial block of information.	Used when only a portion of the tape is read. Eliminates having to read all the way to the end of the tape. If it is part of the tape input information it will always be located in last block.
TAPE SEARCH MODE	Allows the control to position the tape to any location as selected by the operator on the control panel.	Used for restart of tape at the selected location thus avoiding unnecessary machining. Also used to remachine out of tolerance parts where only a portion of the tape is needed.
TOOL LENGTH COMPENSATION	Adjusts the 2-axis position of a tool to correct the difference between the programmed set length and the actual set length.	Saves tool setup time by eliminating additional time required to set the tools to a preselected length. Also allows adjustments of tool length without physically handling the tool when wear and material conditions cause variances exceeding print tolerance.
ZERO RESET	Allows the operator to set the present machine position to absolute zero for any or all axes.	Used with floating zero machines to allow free positioning of part or fixture at setup then aligning the machine to the part location.

20

STATUS MONITORING FUNCTIONS

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
ANNUNCIATOR DISPLAY	Display of "English type" status messages.	Clear and concise way of communicating with the operator.
AXIS POSITION DISPLAY	This is a read out which displays the distance that the axis has moved away from zero. The read out is continuous and changes as the axis moves in either direction.	This display is very useful as a check against incoming command data and becomes a necessity when incremental programming is used since after a series of short moves the operator will know the absolute distance that each axis is from zero.
CYCLE ON METER	Displays in digital form the elapsed time in hours that the machine tool has been under tape cycle control.	This feature would be useful to management for record keeping of productive time.
INPUT DATA ERROR INDICATION	This function is used to monitor the incoming data as each block is read in. If some portion of the data is incorrect, the machining is stopped and an error condition is displayed. In some controllers each register of the instruction can be checked to see which data is at fault.	Without this check of incoming data, simple tape errors could cause serious damage to the workpiece or the machine. Some controllers have the ability to display the data field that is at fault in order to help pinpoint the error.
INTERNAL REGISTER DISPLAY	An operator can select a visual display of digital data from various storage registers within the NC controller.	These displays are used by the operator to monitor the status of the NC system. They are also helpful in determining the cause of a failure.
OVER TEMPERATURE INDICATION	A panel light or temperature indicator warns the operator of excessive temperature in designated portions of the NC system.	Excessive heat can build up as a result of overloading or malfunction of equipment. Indicators are normally provided to warn of this condition.

21

STATUS MONITORING FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
OVER-TRAVEL LIMIT INDICATION	This function produces a visual or audible signal when the machine table travel exceeds the manufacturer's present limits.	Machine tools are usually equipped with over travel limit switches which stop the axis drive when it has passed its limit of travel. A panel lamp is often added to the NC controller to indicate this error condition. It is an aid to the operator telling him why the machine has stopped. If a machine were not equipped with over-travel limit switches, the drives and lead screws could be damaged should they exceed their limit without being stopped.
PARITY ERROR INDICATION	The parity of incomming data is compared with the expected parity. If an error is detected, it is indicated to the operator and execution of the controller is normally halted.	This is a safe guard feature that protects against executing a faulty block of data. The feature can detect contaminated tapes, mechanically deficient tapes and reader failures. Machine execution of data obtained with any of these failures could lead to severe damage to the machine or work piece.
POWER ON METER	An elapsed time meter is used to record the cumulative hours that the machine controller or in some cases the spindle motor has been consuming electrical energy.	Enables a user to manually extract elementary data on machine utilization.

STATUS MONITORING FUNCTIONS (CONTINUED)

FEATURE	TECHNICAL DESCRIPTION	FUNCTIONAL IMPACT
SEQUENCE NUMBER DISPLAY	Displays in a digital form the particular block of tape information being processed at any time.	In the event of a machining problem, sequence numbering by the part programmer and display to the operator will help to pinpoint where the trouble is located in the part program documentation.
SERVO LAG DISPLAY	Displays servo lag for each axis.	Used to assist in setup and maintenance.
SPINDLE LOAD METER	This function provides a read out display that indicates the relative power being used by the spindle drive motor.	This feature provides the user with the ability to assess the power being consumed for any machining operation. It provides both a check on exceeding the input power requirements and a guide by which heavier cuts can be taken without inflicting damage to the machine.
SPINDLE SPEED DISPLAY	Displays in analog or digital form the actual spindle speed at any time.	Assists operator in manually adjusting the spindle speed or in monitoring the process in the event that a constant surface feet per minute has been programmed.

23

INITIAL DISTRIBUTION

Copies

1	ASD(I&L) WP/L. Lehn
5	DIPEC/G. Smith
1	DARCOM/Col. N. Vinson
2	ARMY ELECTRONICS COMMAND

     1   D. Ruppe
     1   J. Potoczniak

1	ARMY TANK - AUTOMOTIVE COMMAND/E. Urban
3	IBEA

     1   R. Geiss
     1   C. McBurney
     1   G. Ney

2   AMETA

     1   J. Young
     1   A. Takemoto

1	ARMY MATERIALS + MECHANICS RESEARCH CENTER/N. Rosato
1	ARMY NATICK LABORATORIES/M. Lynch
1	HARRY DIAMOND LABORATORIES/G. Appel
1	EDGEWOOD ARSENAL/K. Coulson
1	FRANKFORD ARSENAL/S. Hart
2	PICATINNY ARSENAL

     1   R. Laverdiere
     1   D. O'Connor

1	ROCK ISLAND ARSENAL/J. Fox
1	WATERVLIET ARSENAL/D. Ippolito
1	ARMY AERONAUTICAL DEPOT MAINTENANCE CENTER/J. Dugan
1	LEXINGTON-BLUE GRASS ARMY DEPOT/D. Chapman
1	SAVANNA ARMY DEPOT/G. Wagner
1	TOOELE ARMY DEPOT/L. Williams
2	NAVMAT

     1   04H Capt. L. Dittmar
     1   03521 T. Kleback

2   NAVSEA

     1   SEA 07013 R. Gates
     1   SEA 07013A R. Schneck

2   NAVSEC

     1   SEC 6105B/W. Dietrich
     1   SEC 6105B/R. Parrott

2	NAVAIR/R. Gasper
2	NRL

     1   L. Murphy
     2   N. Maddage

Copies

1	NELC/G. Myers
1	NEAC/G. Garreau
1	NTS KEYPORT/T. Genengels
1	NUSC/J. Buela
1	NWC/J. Anderson
1	NSWC Dahlgren/ G. Allensworth
1	PACIFIC MISSILE RANGE/J. Marble
1	NSWC White Oak/J. Fleischman
3	NOS LOUISVILLE

    1   W. Exely
    1   R. Hegler
    1   D. Burnett

1	NAVSHIPYD BREM/D. Podraza
1	NAVSHIPYD CHASN/C. Murry
1	NAVSHIPYD LBEACH/F. Nigro
1	NAVSHIPYD MARE ISLAND/R. Radick
1	NAVSHIPYD NORVA/W. Sawyer
1	NAVSHIPYD PEARL/Bennet
1	NAVSHIPYD PHILA/H. Rilling
1	NAVSHIPYD PTSMH/W.J. Hagerty
2	NAVMIRO

    1   L. Walton
    1   LCDR D. Jordan

1	NARF ALAMEDA/J. Padilla
1	NARF CHERRY PT/L.W. Hartsell
1	NARF JACKSONVILLE/G.D. Barton
1	NARF NORFOLK/E. Amick
1	NARF PENSACOLA/C.R. Flowers
1	NARF SAN DIEGO/J. Obendorfer
1	NAFI/J. Proper
1	AF Hq./Lt. Col. D. Spongberg
1	AFLC/R. Inesta
3	AFML

    1   Dr. C. Pierce
    1   D. Wisnoski
    1   W. Harris

1	HILL AIR FORCE BASE/R. Deru
1	KELLY AIR FORCE BASE/K. Eikenhorst
1	MC CLELLAN AIR FORCE BASE/D. Sturdevant
1	ROBINS AIR FORCE BASE/C. Grimes
2	TINKER AIR FORCE BASE

    1   Kraber
    1   R.P. Griffith

CENTER DISTRIBUTION

Copies

1	40/04/42, Capt. R.E. Sugg
1	1800, G.H. Gleissner
1	1850,.T. Corin
46	1858, B. Smith
1	4201, A. Robson
1	422, F. Costantino
1	423, J. Raines
12	DDC ← ←